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NONLINEAR PROCESSES IN PLASMAS.(U)
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9 FINAL TECHNICAL REPORT, 1 Jan 75 - 31 Dec 79

6 NONLINEAR PROCESSES IN PLASMAS.

by

10 Russell M. Kulsrud

Sponsored by: Air Force Office of Scientific Research

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CONTENTS

SUMMARY

This final report covers the work carried out under Contract F44620-75-C-0037 between the Air Force Office of Scientific Research and Princeton University during the period January 1, 1975 to December 31, 1979.

In accordance with the Contract, research was authorized in the following two areas:

1. The study of the plasma state of matter, with particular emphasis on its nonlinear collective effects.
2. The application of knowledge gained of the plasma state to the interpretation of various dynamic phenomena in which collective effects play a role, such as anomalous transport phenomena, nonlinear wave absorption, and plasma-wave turbulence, both in the laboratory and in space.

In this report the principle results obtained are surveyed in Part I, papers published are listed in Part II, graduate theses supported are listed in Part III, and research personnel engaged are listed in Part IV.

I. ACTIVITIES AND ACCOMPLISHMENTS

One of the main efforts made under this contract was that of the development of a technique in nonlinear plasma theory strong enough to determine the saturation level of many important plasma instabilities—renormalization theory. Its development has arisen out of the consideration of two important plasma transport problems; plasma transport associated with convection cells and also anomalous plasma transport associated with the breakup of magnetic surfaces by drift waves. Interest in both of these problems arose from attempts to understand the experimentally observed large electron thermal transport in tokamak plasmas. In papers 5, 13 and 14 the renormalization theory was sufficiently developed to understand how the level of convection cells was determined in uniform magnetic fields. However, it was shown in paper 36 that convection cells cannot play a large role in nonuniform magnetic fields. Renormalization theory was further developed in papers 22, 34, 38, 40 and 41 in an attempt to investigate the magnetic field breakup by drift waves and the stochastic behavior of particles in the associated microfield structure. Enough progress was made to determine the magnitude of the associated transport, and this may be consistent with that observed experimentally. The basic advances in renormalization theory are summarized in paper 47.

Closely associated with this latter work, a large amount of effort has gone into investigating the stability of drift waves in sheared magnetic fields—published in papers 27, 28, 35, 46 and 54. It is found that the drift wave in slab geometries is always linearly stable, although it may be nonlinearly unstable, and unstable in toroidal geometries.

At present it seems more likely that anomalous transport is caused by magnetic field breakup than by convection cells.

A number of papers (17, 18, 32, 42, 50, 51 and 53) have been devoted to the problem of the rate of magnetic reconnection near x points, and in tearing modes. It appears that the tearing mode rate is the fastest rate at which magnetic fields may reconnect. This rules out magnetic reconnection as a source of energy for solar flares and seems to limit the speed at which plasma can get across the fields in various plasma guns. Further, these results indicate that the small scale magnetic field breakup discussed above is produced by drift waves rather than tearing modes.

Some papers have been devoted to the physics of energetic particles. In papers, 10, 33, 37, and 43 the known result that the relative bulk velocities between a population or beam of energetic particles and a plasma be less than the Alfvèn speed is substantiated. In papers 11, 15, and 24 the production rate of energetic electrons by the runaway phenomenon is determined and shown to be consistent with experiment. The various processes of stochastic production of energetic particles are investigated in papers 7, 8, 19, 20, and 39 and some new light is thrown on the phenomena of Fermi acceleration and the particle behavior in a free electron laser.

The ionosphere provides a convenient laboratory for testing many plasma pheomena such as strong wave plasma effects and plasma turbulence theories. These pheonomena have been studied in papers 1, 2, 23, 29, 30 and 52. In paper 29 interesting limits are placed on the amount of power that can safely be beamed to earth by the proposed Satellite Power Station. In paper 52 the important Novozhelov-Savel'yev experiment is explained.

Other interesting investigations have been carried out, but the above described research represents the bulk of that carried out under the auspices of this contract.

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Adilnawaz B. S. Hassam, "Characteristics and Lifetime of Convective Plasma Motions in Tokamaks," August 1978.

Robert G. Kleva, "Aspects of the Statistical Theory of Stochastic Magnetic Fields: Test Particle Transport and Turbulent Collisionless Tearing Mode," January 1979.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During the five years duration of this contract, 13 scientists produced fifty nine publications. One topic explored was the development of a technique in nonlinear plasma theory powerful enough to determine the saturation level of many important plasma instabilities. This work applies understanding to electron thermal transport in tokamak plasmas, convection cells in uniform magnetic fields, magnetic field breakup by drift waves, and the stochastic behavior of particles in the associated microfield structure. In studying magnetic reconnection near

x points, it appears that the tearing mode rate is the fastest rate at which magnetic fields may reconnect. Other studies included the physics of energetic particles, and established a limit on the amount of power that can be safely beamed to earth by satellite.

IV PERSONNEL SUPPORTED

Name	'75	'76	'77	'78	'79
P. K. Kaw		X	X	X	X
J. A. Krommes			X	X	X
R. M. Kulsrud	X	X	X	X	X
C. R. Oberman	X	X	X	X	X
F. W. Perkins	X	X	X	X	X
E. J. Valeo			X	X	X
E. G. Zweibel	X				
E. A. Adler	X	X	X	X	
Y. Y. Kuo	X	X			
P. N. Guzdar		X	X		
H. E. Mynick					X
E. A. Foote					X
H. Cohn		X	X		